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Performance Improvement of OFDM for Wireless Communication Systems

Synopsis

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ABSTRACT

Orthogonal frequency division multiplexing (OFDM) is a type of multicarrier modulation (MCM) technique in which entire bandwidth is divided into large number of small sub-carriers and each subcarrier is transmitted parallel to achieve higher data rates. It has various applications like Digital audio broadcasting (DAB), Digital video broadcasting (DVB) and wireless LAN. OFDM is an attractive modulation scheme with strongly efficient in bandwidth usage, immunity against multipath fading environment. It has less Inter channel interference (ICI), Inter symbol interference (ISI) and provides better spectral efficiency. OFDM has various merits over the conventional digital modulation techniques however, there are certain limitations of OFDM such as high Peak to average Power ratio (PAPR), high bit error ratio (BER) and synchronization problem.**. PAPR is a measure of the envelope fluctuations of a Multicarrier signal and it is used as figure of merit. A technique called Selective Mapping (SLM) has been used to improve the PAPR. Selective mapping (SLM) is a type of signal scrambling technique in which input data sequences are multiplied by each of the phase sequences to produce alternative input symbol sequence. As per literature survey various modifications in SLM technique have been suggested to improve PAPR but still there is a lot of scope for further improvement. This research work will be carried out to propose a new/ modification in the existing SLM technique which may further improve the PAPR, BER and synchronization Problem. The proposed method will be implemented using MATLAB tool.**

Keywords: Orthogonal Frequency Division Multiplexing *(OFDM),* Selective Mapping *(SLM),* peak-to-average-power-ratio *(PAPR),*Bit Error Ratio (BER), *MATLAB*

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1. INTRODUCTION

As there is a demand for very higher data rate and for this an efficient modulation technique is used which is known as OFDM. OFDM stands for orthogonal frequency division multiplexing which is a multicarrier modulation (MCM) technique and have efficient use of bandwidth. It is an effective and efficient method for transmitting high speed data in mobile communication, Digital terrestrial mobile communication, Digital Audio Broadcasting (DAB), Digital Video Broadcasting terrestrial(DVB-T),wireless asynchronous transfer mode(WATM), Modem/ADSL[1] . OFDM has various merits over other existing digital modulation methods such as more resistant to selective fading, ability to recover from the interference and inter symbol and inter frame interference (ISI), effective and suitable utilization of available spectrum [2].However, one major limitation of OFDM method is high peak to average power ratio (PAPR) [3-4].High value of PAPR will cause clipping in OFDM signal and enable an amplifier to operate in nonlinear section. Due to the presence of this nonlinearity, it will results in in-band distortion and out-band radiation. They have adverse effect such as the in –band distortion will degrade the performance of the system and out-band radiation results in causing interference among adjacent channel. Thus this additional interference in the system will results in increasing Bit Error Rate (BER). One way to overcome this situation is to use high dynamic range linear power amplifier, but utilization of this solution is not effective and too expensive.

The proposed work is organized in different sections. Section 2 describes the literature review of PAPR in OFDM system. Section 3 gives brief description about Orthogonal Frequency Division Multiplexing & PAPR problem.The objectives of the study is presented in section 4. Section 5 describes the methodology used for the work. Lastly the conclusion is represented in section 6.

2. LITERATURE REVIEW

PAPR is a measure of the envelope fluctuations of a Multicarrier signal and it is used as figure of merit. As OFDM signal consists of a number of independently modulated symbols. The sum of independently modulated subcarriers can have a large amplitude variation which produces a large *peak-to-average-power ratio* (PAPR).PAPR reduction techniques can be divided into two types. These are signal scrambling techniques and signal distortion techniques [24].The signal scrambling techniques are classified as:

- Block Coding Techniques
- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS)
- Interleaving Technique
- Tone Reservation (TR)
- Tone Injection (TI)

The Signal Distortion Techniques are classified as:

- Peak Windowing
- Envelope Scaling
- Clipping

In 1996, Huben et al. proposed a selected method (SLM) where side information is required at the receiver to recover the original signal. However this method introduces data rate loss & BER degradation. **In 1997, Telledo & cioffi** proposed a tone Reservation method. In this method certain number of subcarriers or tones is used for PAPR reduction. Some tones that are reserved for PAPR reduction is known as PAPR reduction tones (PRT). Since PRT are not used for data transmission & so it results in data loss. **In 1998, Cimini** et al. proposed a simple clipping and filtering technique. It reduces the peak power by clipping the signal to the desired level. This method is non linear & causes in band & out of band distortion, degrades the BER and bandwidth efficiency.**In 1999,Wang** et al. proposed a scheme μ law companding scheme to reduce PAPR .It is better than clipping &filtering but the BER performance degrades. **In 2000, cimini et al.** proposed a Partial Transmit method (PTS) which reduces the PAPR but the complexity increases as number of partition increases .If the partition are more, than the IFFT operations will be more. **In 2000, Park** et al. proposed a PAPR reduction technique in SLM-OFDM system which is performed by choosing the rows of Hadamard matrix as phase sequence. The elements are either 1 or -1, two phases are used .The reduction capability of this matrix is

limited. **In 2002, Jean Armstrong** proposed the repeated clipping & filtering scheme in which clipping &filtering operations are repeated several times to reduce both out of band &PAPR. The performance depends upon the iterations and more iteration reduces the PAPR. But it causes complexity and distortion. **In 2002, Nikookan** et al. proposed SLM based OFDM using different types of phase sequence set. These sets have different PAPR performances for same number of alternative sequence.**In 2004, Huang et al.** proposed a companding method which results in acceptable PAPR but introduces non linear distortion, BER degradation and in band distortion.**In 2004,Hunag** et al. proposed four companding transformation functions i.e. linear symmetrical transform, linear non symmetrical transform, non linear symmetrical transform & non linear non symmetrical transform. Linear non symmetrical transform (LNST) performs the best PAPR reduction. **In 2005,** Jiang et al. proposed an exponential companding scheme to transform Rayleigh distributed OFDM signal magnitude into uniform distribution. It results in less design flexibility. **In 2007, Jiang** et al. proposed a non linear companding transform to effectively reduce the PAPR.In this method the companding function is separately applied to I & Q components of OFDM signal. The large values of I &Q are compressed & small values of I &Q are enlarged but it decreases the value of BER. **In 2007,P.cheng** et al. proposed chaotic sequence based set generation which is superior than Hadamard .**In 2009, Aburakhia** et al. proposed linear companding transform (LCT) that treats large &small signals on different scales but uses two inflexion points that produce more flexibility in designing. As the transformed function changes abruptly at inflexion points & hence it degrades the PSD (power spectral density).**In 2009,Hou** et al. proposed a trapezoidal companding which reduces BER .This scheme transforms the Rayleigh distributed OFDM signal magnitude into trapezoidal distribution which results in large peak values.

In 2009, Maruyana et al. proposed a method to use a new phase set generation based on m-sequences. In first phase sequence is generated by multiplication of two m sequence & remaining phase sequence are generated by multiplication of m sequence with cyclic shifted m sequences. This method is complex. **In 2011,Jung** et al. proposed trapezium distribution based companding to transform Rayleigh distributed OFDM into a biased linear distribution. **In 2013,Goel** proposed a quadrilateral companding transform which provides additional degree of freedom in comparison to existing schemes and produces low BER & good PAPR reduction. **In 2013, Goel**

proposed a M-2M mapping scheme for PAPR reduction in SLM.It maps M-ary data points to 2Mconstellation points of 2M-ary modulation scheme using two phase rotation factors. It eliminates the requirement of side information (SI) but increases the constellation size by a factor of four which degrades the error performance of OFDM system.**In 2014,Md Munjure** et al proposed a two clipping based filtering method for PAPR reduction .In this method the clipped signal passes through a composed filter(IIR based BPF)before passing through LPF. It results in BER degradation but reduces PAPR more.

It is concluded from the above literature survey that there is still lot of scope to further improve PAPR, BER and synchronization for improving the performance of OFDM.This can be achieved by modifying the existing SLM technique/developing new algorithm.

3. DESCRIPTION OF BROAD AREA

With the rapid development in telecommunication technology, high speed communication is placed at upper most priority level. A wide variety of modulation methods are proposed that fulfill this primary objective in communication. Orthogonal Frequency division multiplexing is one of the technique used to provide higher data rate. Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation (MCM) method used for wireless communication, Digital audio broadcasting(DAB),Modems and ADSL[1].This technique has various advantages over other existing methods such as more resistant to selective fading, ability to recover from the interference and inter symbol and inter frame interference (ISI), effective and suitable utilization of available spectrum[2].OFDM suffers from high peak to average power ratio(PAPR) [3-4].High value of PAPR will cause clipping in OFDM signal and enable an amplifier to operate in nonlinear section. This nonlinearity will result in in-band distortion and out-band radiation. They have adverse effect such as the in –band distortion will degrade the performance of the system and out-band radiation results in causing interference among adjacent channel. Thus this additional interference in the system will result in increasing Bit Error Rate. One way to overcome this situation is to use high dynamic range linear power amplifier, but utilization of this solution is not effective, and too expensive.
As OFDM signal consists of multiple modulated carriers and able to generate a high peak to average power ratio (PAPR), when these parallel carriers are added up. If N carrier signals which are added together constitute same phase then they generate a peak power which is N times the average power. The increased value of PAPR factor results in clipping noise, non–linear distortion of Power amplifier, BER performance debasement and enhances complexity factor in analog to digital (A/D) or digital to analog (D/A) converter.

PAPR means Peak to average power ratio. It is defined as the ratio of Peak power to the average power [16].It is mathematical represented in equation (1)

$$PAPR_{dB} = 10\log\left(\frac{max[x(t)x^*(t)]}{E[x(t)x^*(t)]}\right) \quad \text{----------(1)}$$

Where ()* corresponds to the conjugate operator.

Currently there are various methods for reducing PAPR in OFDM technique. The first method is distortion method .However, this method is easier and simpler but it decreases the performance of OFDM. The second method is coding technique [5]. This method is suitable for reducing the PAPR for small number of subcarriers but it is not used for large number of subcarriers. The third method includes probabilistic or redundancy methods such as selective mapping (SLM) and the Partial transmit sequence (PTS).

These techniques are described as follows:

3.1 Signal Distortion Techniques

It is a type of PAPR reduction technique which is simpler but it decreases the performance of OFDM .They are classified as:

Peak windowing

This technique is similar to the clipping technique but it gives better performance by adding some self interference and increasing in BER (bit error rate& out band radiation) .In this method we multiply different windows with large signal peaks e.gs Gaussian shaped window, cosine, Kaiser etc .OFDM signal is then multiplied with several of these windows, the resulting spectrum which is obtained is a convolution of the original OFDM spectrum with the spectrum of the applied window (as mentioned earlier). Means the windows should be narrow as possible. By using this technique PAPR can be reduced to 4db of each subcarrier.

Envelope Scaling

This technique is related to scaling means before OFDM signals sent to the IFFT all sub carrier is scaled the input envelope. This technique uses 256 sub carrier so that all sub carriers will remains equal. In this method the input envelope in some sub carrier is scaled to achieve the smallest amount of PAPR at the output of the IFFT. The receiver does not need any side information at the receiver end for decoding. This method is suitable for the PSK modulation but when it is applied with the QAM high degradation is occurred in terms of BER

Clipping Technique

The Clipping based techniques clips the time domain signal to predefined level. The OFDM signal contains high peaks so it is transferred from the clipping. In this when amplitude crosses

the threshold or cut off level, the amplitude is clipped off while saving the phase. It is easier and simpler but it is a cause for decreasing the performance of system [5].

3.2 Signal Scrambling Technique

This technique is most commonly used as it doesn't distort the signal. Different types of signal scrambling techniques are:

Block Coding Technique

It is a kind of signal scrambling technique. In this technique PAPR is reduced by using different block coding and various set of code words. This scheme is most commonly used to reduce the peak to mean envelope power ratio.

Selective Mapping Technique

The input data sequences are multiplied by each of the phase sequences to generate alternative input symbols sequences [1]. For the IFFT operation, each of these alternative input data sequence is used and then the one with the lowest PAPR is selected for transmission as shown in Figure 1

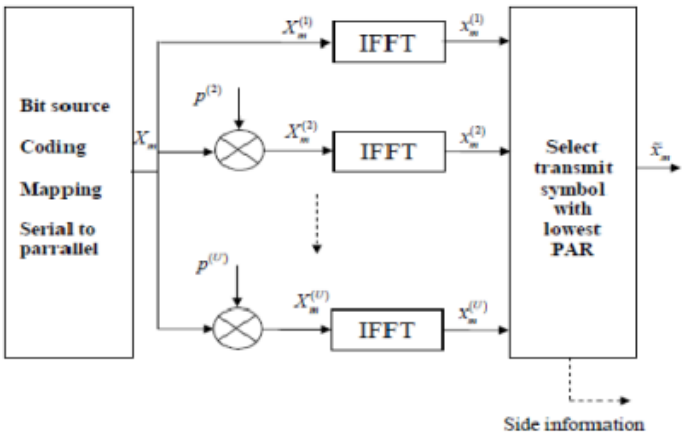

Figure 1 Selective Mapping Method

Partial Transmit Sequences

In this method it divide the original OFDM sequence into several sub-sequences and then for each sub-sequence is multiplied by different weights until an optimum value is chosen shown in Figure 2.[6]

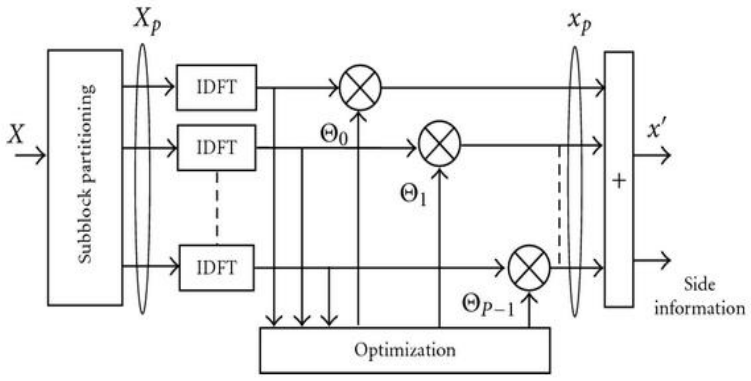

Figure 2 Partial Transmit Sequence Method

Interleaving Technique

It is a type of phase rotation method which is widely used to reduce PAPR (peak to average power ratio) in orthogonal frequency-division multiplexing (OFDM) system. This method reduces the PAPR without spectrum distortion. This technique requires many IFFT blocks and the side information must be additional included for the correct data recovery. As the side information is used so the data rate and spectral efficiency decreases which results in lowering the value of BER.

Tone Reservation

It requires some set of reservation of tones. Reserved tones can be used to minimize the PAPR and it is used in multicarrier systems. If number of tone is small then reduction in PAPR may represent non negligible samples of available bandwidth. In this method there is no requirement of side information and no process is required at the receiver. In this method the data block is added to the time domain signal to reduce the peak leads.

Tone Injection

It uses additive method for PAPR reduction .This method leads to less data rate loss. This method used the set of active constellation point for an original constellation point to reduce the PAPR. In this method for each unit, all original constellation is mapped on the several equivalent constellation point and this extra point freedom can be easily used to reduce the PAPR.This

method deals with injecting tone of appropriate phase and frequency in OFDM symbol. The limitation of this method is the requirement of side information at the receiver side.

Based upon the literature review the SLM technique is better than existing techniques. So the research work will proposed the modified SLM technique which will reduce the PAPR as compared to the existing SLM technique. By combining the selective mapping method with the QPSK technique, not only useful in decreasing the complexity factor at receiver but also decreases the PAPR in OFDM method.

4. OBJECTIVES

OFDM is a type of multi-carrier modulation (MCM) technique which transmits signals through multiple carriers. These multiple carriers (subcarriers) have different frequencies and all subcarriers are orthogonal to each other. It is used in both wired (ADSL) and wireless communications (wireless LAN) [1].OFDM system has less interference because of the presence of orthogonal subcarriers. So OFDM system is widely used in wireless communication .OFDM suffers from high Peak to average power ratio (PAPR).It results in non linearity in power amplifier and hence the performance of OFDM system degrades.

The objectives of this research work are:

1) To survey the relevant literature for PAPR,BER and synchronization in OFDM.
2) To simulate the existing SLM technique for PAPR and propose the modified/new algorthim for further reduction in PAPR.
3) To propose another algorthim for reduction in BER.
4) To reduce the synchronization problem of the proposed OFDM system
5) To improve the overall performance of proposed OFDM system

5. METHODOLOGY

SLM technique is a promising method for reducing PAPR because it does not produce distortion. In this scheme, data blocks are firstly converted into several independent blocks and the block with lower PAPR is sent, in which converting process involves multiplying data sequences to random phase sequences generated. The proposed work is modeled using existing SLM with cyclic coding which not only reduces the value of PAPR but also increases the performance of OFDM. Following algorithm is used for the proposed work to reduce the PAPR.

1) Initialize the parameters (e.g. branch number K in SLM)
2) Generate OFDM symbols with QPSK modulation for each subcarriers and set weights for SLM method.
3) Apply proposed SLM technique with cyclic code for PAPR.
4) Calculate the PAPR value for the proposed work.
5) Compare and plot the complementary cumulative distribution function (CCDF) for different PAPR.

The PAPR calculated for the proposed work will be compared with the conventional SLM method. The flowchart for the proposed work is shown in figure 3.

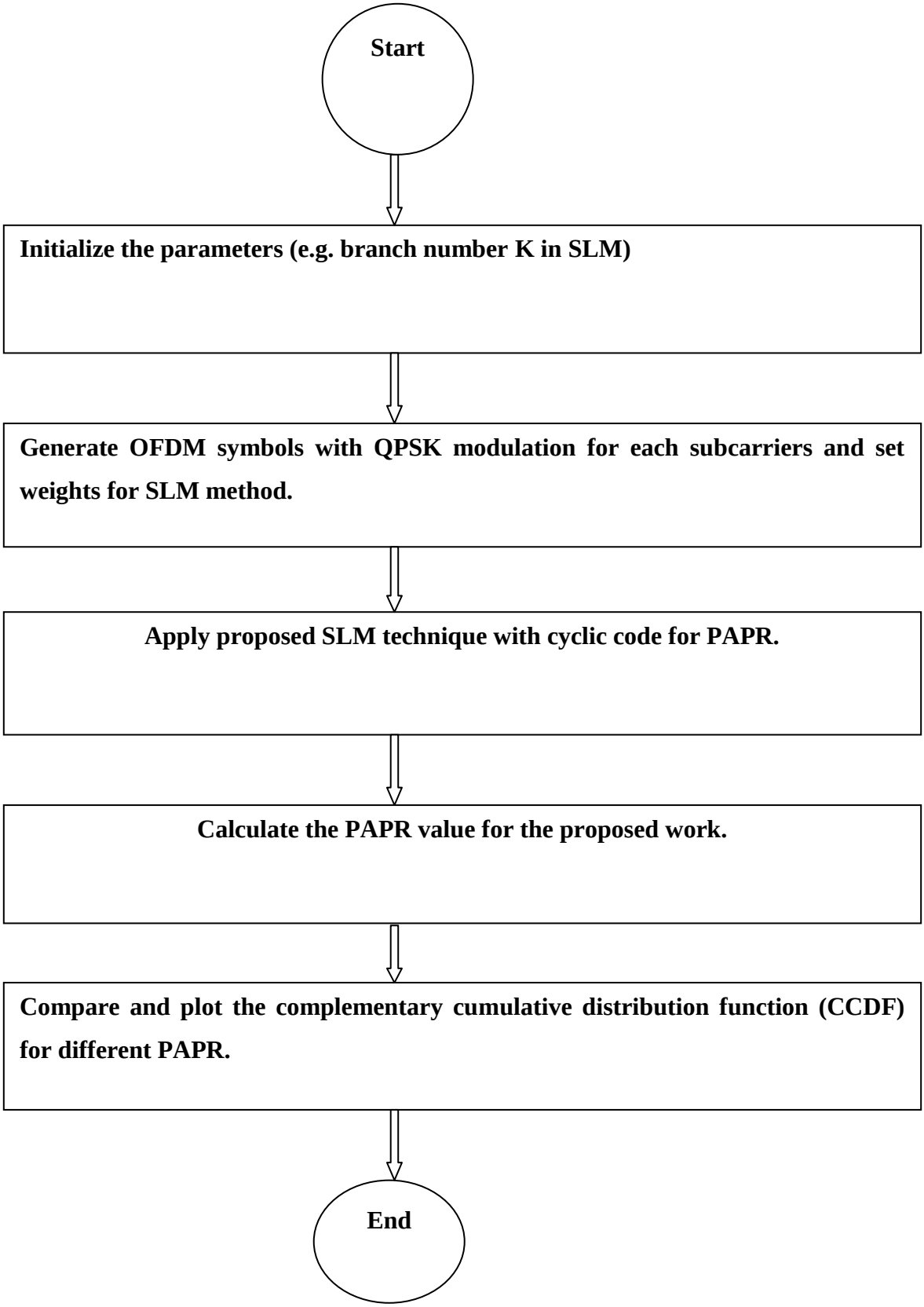
Start
Initialize the parameters (e.g. branch number K in SLM)
Generate OFDM symbols with QPSK modulation for each subcarriers and set weights for SLM method.
Apply proposed SLM technique with cyclic code for PAPR.
Calculate the PAPR value for the proposed work.
Compare and plot the complementary cumulative distribution function (CCDF) for different PAPR.
End

Figure 3 Flowchart of proposed work

The schedule plan has been shown in figure 4**.**

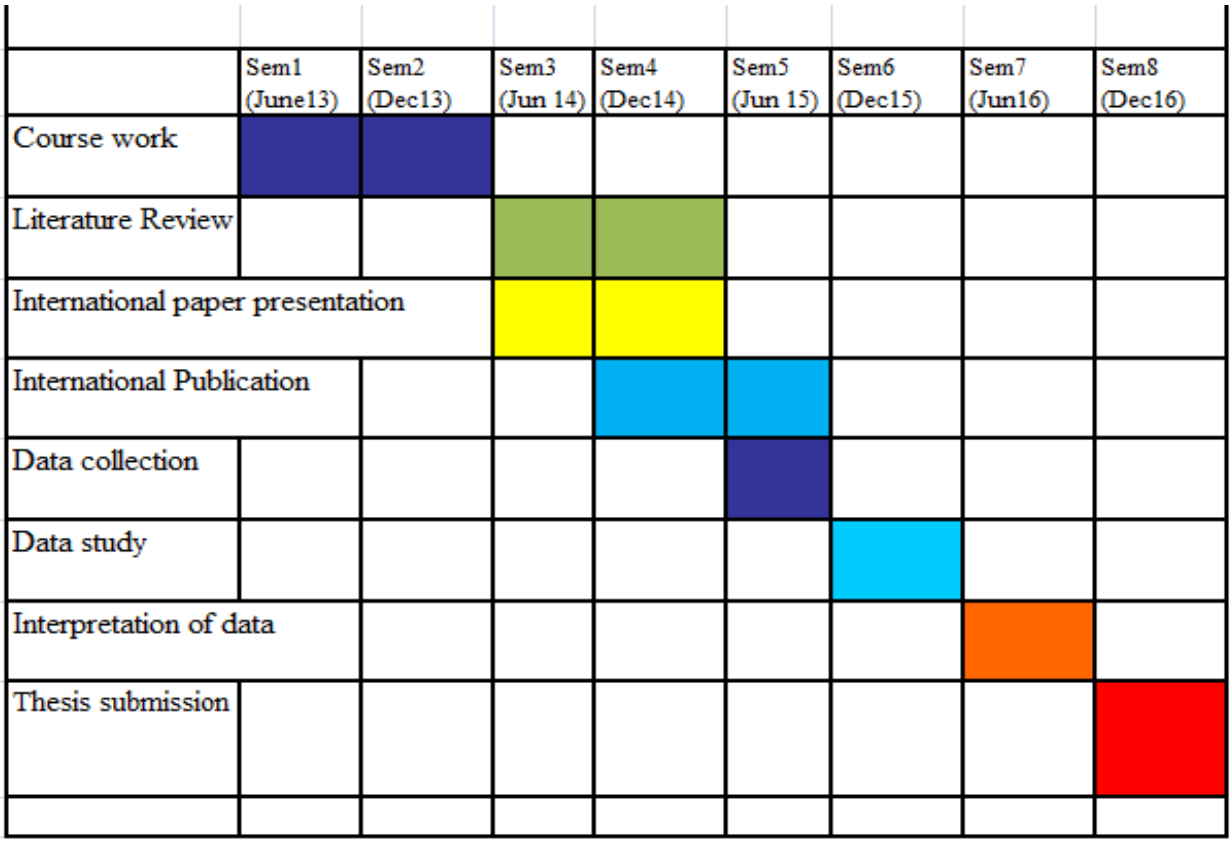

Figure 4 Time schedule Plan of Research Work

6. CONCLUSION

Orthogonal frequency division multiplexing (OFDM) is a high speed modulation technique which produces high data rate and used in both wired and wireless systems. The major problem of OFDM system is PAPR which alter the performance of OFDM. Various techniques are available which will improve PAPR and all these techniques have its own merits and demerits. If the demand for proper utilization of spectrum will increase, then OFDM turn invaluable to fulfill requirements for future generation. The proposed work will not only reduce the PAPR but also reduces BER and enhances the performance of OFDM systems.

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